Disposition of Three-Phase Lines

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THE JOURNAL OF ELECTRICITY, POWER AND GAS.

VOLUME VIII. SAN FRANCISCO, NOVEMBER, 1899. NUMBER 5.

The Disposition of Three-Phase Transmission Lines.

BY AUG. J. BOWIE, JR.

IN alternating systems, the proper arrangement on the poles of the wires relatively to each other, becomes a matter of great importance in many cases. If the wires are badly arranged it may lead to serious interference with the regulation of the systems: raising the pressure in some circuits and dropping it in others, far out of proportion to the loads which they have to carry. The common remedy is to start in spiraling the wires, and usually it is regarded that the more spirals put into the lines, the better is the system arranged. This very often leads to the extreme, and many more spirals than necessary are used. Spiraling is a thing which should be avoided as much as possible, since it not only introduces complications into the system, but also is more or less a source of danger in transmission lines, where, if poles are not double armed at the spirals, the burning off of a single pin will let the wires come together, thus short-circuiting the line.

The idea of spiraling is to obtain (1) equal induction in any circuit; (2) no mutual inductance between circuits.

In transmission lines in order to obtain equal induction between the wires of a three-phase system, the wires are usually arranged on an equilateral triangle. In this event spiraling would be necessary only in order to avoid mutual inductance of the circuits, since the wires are so placed that, with a balanced load, the drop is equal in all. However, it is not necessary to arrange the wires on a triangle, but they can be placed on the same cross-arm and spiraled so as to have just the same effect. In case two circuits are run on a pole line the advantage of the latter arrangement is the saving of the additional cross-arms, and hence also there is a gain in height of the wires above the ground. The disadvantage is that the effective distance between the wires as regards induc-

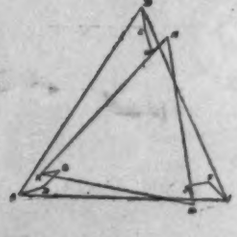


FIGURE 1.

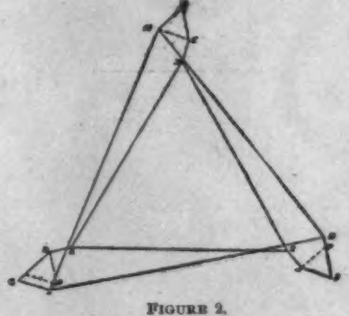


FIGURE 2.

tance is increased to about five-fourths of its value in the preceding case, for a given minimum distance between wires, and, in case this distance is large, it will require very long cross-arms.

In distribution lines, it is very often inconvenient to place the wires in the form of a triangle, and hence it is important to know how great the effect of unequal inductance will be, so as to know whether it is worth while to spiral the lines.

First take up the general case, supposing that the voltage triangle at the start is known, and that the currents and their phase relation are also known. The inductive effect on the A leg will be proportional to the number of lines of force which B causes to pass between A and B, plus the number of lines of force which C causes to pass between A and C—the sum being the vector sum.

This follows, since this is equal and opposite to the sum of the unbalanced lines of force cutting A; the vector sum of the currents in B and C being equal and opposite to the current in A. In this way it is easy to make either a graphical or an analytical solution of the problem.

All that is necessary is first to draw the voltage triangle. Next lay off a line from each of the vertices, representing in phase and magnitude the IR component of that particular wire. Next lay off, as mentioned, from the end of each such line, and 90° in phase behind each of the other currents, the inductive effect on the leg in question.* This inductive effect is equal to the reactance of a circuit of one-half the length of the circuit in question, multiplied by the appropriate current. In this way, the potential of the receiving end relatively to the transmitting end, is determined for each wire, and by joining the three points thus found we have the voltage triangle received.

Let $A\ B\ C$ be the order of rotation of the phases. In the general case, suppose the wires are any distance apart, no matter how irregularly spaced, and let the values of the three currents and their phase position be known. Let $A\ B\ C$ (Figure 1) be the voltage triangle at the station. Let the the problem be to find the voltage triangle at the place where the line or feeder ends. Call the resistances of the lines $R_a\ R_b\ R_c$ and the reactances of the circuits $2L_{ab}\ 2L_{bc}$ and $2L_{ac}$ respectively. Let the currents be $I_a\ I_b$ and I_c respectively. Lay off AD in phase with I_a and equal to I_aR_a. Similarly, BE equals R_bI_b and CF equals R_cI_c—being laid off in phase with their respective currents. Next draw $DG = I_cL_{ac}$ 90° behind CF. Then draw $GK = I_bL_{ab}$ 90° behind BE. Then K represents the position of the voltage of the end of the A feeder. Similarly, points M and N may be found for B and C. Then KMN will be the required voltage triangle.

The special case where the load is balanced is of more interest than the general case. Let the voltage triangle, ABC (Figure 2), be delivered to the load, which is balanced, and has a lag angle at the receiving end of ϕ. Let the problem be to find what must be the voltage triangle delivered to the lines at the station in order to deliver the equilateral triangle, ABC, at the end of the line. Let the wires be placed on the same cross-arm, and let the center wire be equidistant from the two others. Suppose the wires are placed thus: $A\ B\ C$, B being the center wire, and let the order of rotation of the phases be $A\ B\ C$. Let R be the resistance of each wire, and let I be the current in each wire. Draw AD, CF, and BE, each of which is equal to RI, and each of which is drawn in its proper phase relation. Let the reactance of $AB = 2L_1$ = the reactance of BC. Let the reactance of AC be

*The voltage consumed in overcoming the effect of induction is 90° ahead of the current causing it. As has been shown, this induction is due to currents equal and opposite to those flowing in the other legs. Hence lines drawn 90° behind the currents in the other legs represent in phase this voltage, which is referred to as the inductive effect.

$2L_2$. Draw $DG = L_2 I$ 90° behind CF, and draw $GK = L_1 I$ 90° behind BE. Then K is the position of the voltage of A at the station. Draw $FJ = L_1 I$ 90° behind BE, and $JN = L_2 I$ 90° behind AD. Draw $EH = L_1 I$ 90° behind AD, and $HM = L_1 I$ 90° behind CF. Then KMN is the voltage triangle which must be furnished by the station. Let $L_2 - L_1 = L^1$. Draw $KO = L^1 I$ parallel to GD, and lay off $NP = L^1 I$. Then OMP is an equilateral triangle, and is the voltage triangle which would have to be furnished by the station provided the wires were arranged on an equilateral triangle on the poles, with sides equal to the distance apart of A and B or B and C. It is evident that $DO = FP = EM = L_1 I$, and that DO is perpendicular to DA, FP is perpendicular to CF, and EM is perpendicular to BE.

In order to find the algebraic expressions for the lengths of the sides of triangle KMN, resolve the components of these sides, along two directions at right angles to each other, and take the square root of the sum of the squares. Resolve for each side, along and perpendicular to a line which would lag ϕ° behind the corresponding side of triangle ABC. Let $AB = BC = AC = V$. Then:

1. $(KN)^2 = (V. \text{Cos } \phi + IR\sqrt{3})^2 + (\sqrt{3}\, L_2 I + V. \text{Sin } \phi)^2$
2. $(KM)^2 = (V. \text{Cos } \phi + IR\sqrt{3} + L^1 I)^2 + (\sqrt{3}\, L_1 I + V. \text{Sin } \phi)^2$
3. $(MN)^2 = (V. \text{Cos } \phi + IR\sqrt{3} - L^1 I)^2 + (\sqrt{3}\, L_1 I + V. \text{Sin } \phi)^2$

If the lag angle is zero (*i. e.*: for a non-inductive load), then these equations become:

4. $(KN)^2 = (V. + IR\sqrt{3})^2 + 3L_2^2 I^2$
5. $(KM)^2 = (V. + IR\sqrt{3} + L^1 I)^2 + 3L_1^2 I^2$
6. $MN = (V. + IR\sqrt{3} - L^1 I)^2 + 3L_1^2 I^2$

It is plain that of the two outside wires, the one which leads the center wire drops more than the one which lags behind it. Let d be the distance between A and B on the pole, and let r be the radius of each wire. Then if l = length of the circuit $L_1 = (2\pi f / 10^9)(2 \log_e d/r + \frac{1}{4}) l$. $L_2 = (2\pi f / 10^9)(2 \log_e 2d/r + \frac{1}{4}) l = (2\pi f / 10^9)(2 \log_e d/r + \frac{1}{4} + 2 \log_e 2)\, l$. Hence, $L_2 - L_1 = (2\pi f / 10^9)\, l\, 2 \log_e 2 = L^1$, and is independent of any quantities except frequency, f, and the length of the circuit. Hence L^1 may be written as equal to $m\, k\, f$, where k is a constant, m being the length of the circuit in miles. The value of k is .0014. From equations 1, 2 and 3, it follows that the effect of this arrangement of wires may be calculated just the same as for three-phase circuits, which are equidistant, provided the following changes are made:

1. KN is calculated as if the three wires were equidistant, $2d$.
2. KM is calculated as if the three wires were equidistant, d, the resistance of each wire being increased $L^1/\sqrt{3}$.
3. MN is calculated as if the three wires were equidistant, d, the resistance of each wire being decreased $L^1/\sqrt{3}$.

For a frequency of sixty cycles, $\frac{L^1}{m} / \sqrt{3} = .048$, being of course, a constant.

If the problem be to find what voltage triangle will be delivered when an equilateral voltage triangle is given to the line at the station, it can be solved in a similar manner.

Evidently the voltage received would not be an equilateral triangle, under these circumstances, with a balanced load. However, if the load consists to any extent of motors, the latter act as equalizers of voltage—the legs receiving the higher voltages, taking more current than those with lower voltages. This reacts on the lines and tends to make the voltage triangle received much more nearly an equilateral triangle than any calculations on the supposition of balanced loads would imply. It is well however, not to rely on motors for such purposes, since, aside from other considerations, the motors are not acting at best efficiency under the circumstances, some legs being loaded more than others. In some experiments made by the writer with eleven per cent. difference of voltage between two of the phases, there was as much as sixty per cent. difference in the current taken by different legs of a three-phase motor. Of course, this was an excessive difference of voltage, and nothing like it should occur in practice.

If the lines are spiraled, running for a third of the distance ABC, for the next third BCA, and for the last third CAB, then with a balanced load, and with the three voltages equal at either end of the line, it follows from the symmetry of the problem that the drops in each of the feeders must be alike. Thus from equations 1, 2 and 3 it is plain that the station voltage of each line must be

$$\sqrt{(V. \text{Cos } \phi + IR\sqrt{3})^2 + (\tfrac{2}{3}\sqrt{3}\, L_1 I + \tfrac{\sqrt{3}}{3} L_2 I + V. \text{Sin } \phi)^2}$$

In other words, that is equivalent to a three-phase line arranged on a triangle, where the reactance of each circuit of the triangle is $2(2L_1 + L_2)/3 = 2L$

Hence $L = (3L_1 + L^1)/3 = L_1 + L^1/3$

Now $L_1 = S. \log_e d/r + T$; S and T being constants when the length of the circuit and the frequency are fixed. Also $L^1 = S. \log_e 2$.

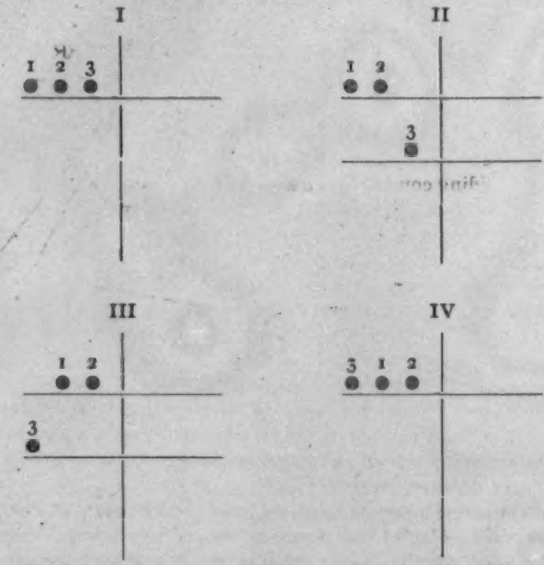
Therefore $L = S. \log_e d^1/r + T$, where d^1 is the side of the desired triangle;

Hence $\log_e d^1/r = \log_e d/r + (\log_e 2)\, \frac{1}{3}$

$(\log_e 2)\, \frac{1}{3} = .231 = \log_e 1.26$. Hence $d^1 = 1.26\, d$, or in other words, the effective distance apart of three wires, when arranged equidistant in a line and spiraled, is equal to 1.26 times the distance apart of the two nearest wires. For instance, if the wires are arranged thus

and spiraled, the inductive loss is just the same as if they were arranged on an equilateral triangle 1.26′ on a side. Of course the inductive drop would not increase in any such ratio. For example, the reactance of a circuit of No. 1 wire per mile of circuit at 60 cycles, with the wires 1′ apart, is 1.130, and the reactance of a similar circuit 1.26′ apart, is 1.185—an increase of only five per cent. In fact, in the case of transmission lines, this will vary from about four per cent. to six per cent. Assuming ten per cent. IR drop, and ten per cent. reactance drop, as representing the average case for fully loaded transmission lines, this will increase the reactance drop only one-half of one per cent., and hence is not of any great importance.

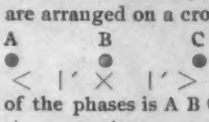
It is possible in transmission lines to spiral three wires arranged on one cross-arm by the use of only one pole with two cross-arms, though a much better plan is to use two poles with two arms each in the manner shown below:



Where it is only a question of avoiding unequal self-induction and not of avoiding mutual induction, the wires may be spiraled

thus: 1 2 3, 1 3 2, 3 1 2. In other words, letting each wire occupy the center position for one-third of the distance. For, obviously, it makes no difference whether the wires are run 1 2 3 or 3 2 1, one arrangement being the same as the other looked at upside down. This is a point which may be made use of in distributing lines, since it is necessary to cut only two of the wires and not all three at each spiral.

To see how great will be the effects of unequal self-induction caused by not spiraling the wires, four examples have been calculated. In each case the supposition is made that an equilateral voltage triangle of 1000 volts on a leg, is delivered to a balanced load from the station which is a mile away. The frequency is 60 cycles, and the wires are arranged on a cross-arm one foot apart thus:



The order of rotation of the phases is A B C. In each case considered, the drop, $IR\sqrt{3} = 50$ volts.

Case 1. Non-inductive load, No. 0000 copper wire. 111 amperes per leg.

Case 2. Non-inductive load, No. 6 copper wire. 13.8 amperes per leg.

Case 3. Power factor .8, No. 0000 copper wire. 111 amperes per leg.

Case 4. Power factor .8, No. 6 copper wire. 13.8 amperes per leg.

Case 1. $I = 111$; $L_1 I\sqrt{3} = 97.8$; $L_2 I\sqrt{3} = 113.5$; $L^1 I = 9.3$; $KN = 1056$; $KM = 1064$; $MN = 1045$; and the drops are 5.6 per cent., 6.4 per cent. and 4.5 per cent.

Case 2. $I = 13.8$; $L_1 = .633$; $L_2 = .72$; $IL^1 = 1.2$; $KN = 1050$; $KM = 1051$; $MN = 1049$; and the drops are 5.0 per cent., 5.1 per cent. and 4.9 per cent.

Case 3. $KN = 1110$; $KM = 1107$; $MN = 1093$; and the drops are 11.0 per cent., 10.7 per cent. and 9.3 per cent.

Case 4. $KN = 1050$; $KM = 1050$; $MN = 1048$; and the drops are 5.0 per cent., 5.0 per cent. and 4.8 per cent.

In the formula deduced, no account was taken of the effect of capacity of the lines. As a rule, only in very long lines run at very high pressures, will the capacity effect become of any importance as affecting the inequality of the three voltages. However, a three-phase circuit with three wires on the same arm, may be spiraled in the following way so as to overcome practically all inequality of voltage due to capacity or leakage:

Run *ABC* one-sixth of the way, then *BCA* one-sixth of the way, then *CAB* one-third of the way, *BCA* one-sixth of the way, and *ABC* the remaining one-sixth of the distance.

DESTRUCTION OF THE BLUE LAKES POWER PLANT.

ABOUT five o'clock A. M., on Wednesday, November 1st, the generating station of the Blue Lakes Water Company, at Blue Lakes City, near Mokelumne Hill, Cal., was entirely destroyed by fire.

The building consisted of a steel frame, covered with corrugated iron. The floors, switchboard platform and frame, the transformer gallery and office, were all wood. The 10,000-volt switchboard was close to the north wall with a 2000-volt board directly in front of it and about eight feet distant. All the transformers were located on a gallery which was supported by the north wall of the building on one side, the 2000-volt board on the other and which covered both boards completely, forming a roof over the space between them. This space was closed at the east end by the office but was open at the other end. The telephone room was located directly at the open end of the boards and in such a position that anyone coming out of the room would see anything going on in the space between them.

On the transformer gallery were three 500-kilowatt, oil-insulated, water-cooled Stanley transformers, two of which were connected to the Stockton circuit, the other being an idle transformer in reserve. These were all located at the east end of the gallery, the two live ones being over the office, and the dead one over and back of the end panel of the 2000-volt board. Besides the three transformers mentioned, there were six 75-kilowatt, air-cooled Stanley transformers connected to the Calaveras circuit, and four others of the same type and make connected to the Amador circuit. The floor and timbering of the gallery were extremely heavy, and additional shores of 6x6 Oregon pine were put in when the large transformers were installed last summer. The floor of the gallery was of tongue and groove pine laid in two layers. All the leads from the board came up from below through large holes in the floor, with no bushings, the air space being depended on for insulation. The whole floor was saturated with oil which had leaked from the transformer cases and from the barrels when the cases were originally filled, to such an extent that oil had dripped through. This leakage was taken care of by placing metal drip pans under the transformers. At the time of the fire these pans had not to exceed one-eighth of an inch of oil in them. The floor was practically free of clear oil, but the wood was saturated from previous leakage. The 25,000-volt board was located in the roof and was in no way involved in the fire until the building collapsed.

Inasmuch as there has been some discussion as to the kind and quality of oil used in the transformers, it may be well to go into some detail on this point. The oil was high grade and known to the trade as "Mineral Seal," 300° test, and was supplied by a responsible firm. A lighted match dipped in it would be extinguished at once. On one occasion, to satisfy one who had complained of the danger of using oil-cooled transformers, a handful of waste was thoroughly saturated in it, then set on fire, and when fully ablaze was immersed in the oil with the result that the fire was instantly extinguished. On two occasions, short circuits in the transformers failed to set fire to the oil, and in one of the instances the short circuit was maintained for nearly ten minutes. The oil was amber color by reflected and steel blue by transmitted light.

Two men were always on watch, a dynamo tender and a helper. Their orders were that in case of trouble the tender was to shut off the water and the helper was to notify the station foreman by telephone. Besides the routine duties of such a station, the tender was required to go on the gallery frequently, and be sure that the water was circulating properly in the cooling coils. He had done this not more than fifteen minutes before the trouble began, and both men were seated in front of the board when suddenly the machines slowed down and all the lights went out. While the tender was shutting off the water the helper ran to the telephone, rang the bell, and without waiting a reply ran back and pulled the three machine switches, and also shut the water off the third wheel. As he left the telephone room he saw burning material dropping down through the wire holes in the gallery floor, also a heavy arcing on the back of the 2000-volt board. Meantime the tender had shut the water off the two end wheels, and had pulled the Amador circuit switches. At this time both men noticed that the marble was cracking and beginning to fall. There was the sound of fierce fire with a great smoke coming from the neighborhood of the oil transformers, and fire was breaking out from the office. Both men then left the building and saved only that which they had on their backs. It must not be supposed that their accounts agree in detail, but they do agree as to the facts stated above.

In about twenty minutes to a half hour later one of the oil transformers fell through the floor, and was followed shortly after by the other two. This added about 2250 gallons of the oil to the flames, and in a little while the building collapsed under the intense heat.

The behavior of the lights on the different circuits is significant. In Stockton, the lamps flickered, went out for a moment, then came up again for one very brilliant flash and then went out to stay. On the Calaveras circuit the same course was observed. On the Amador circuit the same was noticed, except that the lamps did not relight after the first going out. In this connection it should be observed that the Amador circuit was pulled by the dynamo tender, and he stated he pulled this circuit, and only this

one, before he knew there was any difference in the behavior of the three circuits. The most significant fact in this connection is that both phases were affected alike in every way. Both behaved alike, and the changes were simultaneous.

It is inconceivable that both the oil transformers could have failed at precisely the same instant, and yet this must have been the case if the oil transformers were in any way the cause of the fire. It is established beyond doubt that they did not short-circuit, since, as soon as they were cold enough to be handled, they were opened and every foot of wire was wound off from the original coils to a wire reel, in a rigid inspection in the presence of E. E. Stark for the Stanley Electric Manufacturing Company, and A. H. Babcock for the Standard Electric Company. In every coil the wire was continuous and uninjured, and nowhere was there the slightest evidence of a short circuit.

When this examination was concluded, a search was made for evidence of a sudden rush of oil from any of the cases. The only way for oil to get out of the cases was by a leak over the top, or by the breaking of the oil outlet pipe. All three of the outlet valves were found, and in every case the evidence was conclusive that the valves were properly closed. A further demonstration that oil did not leave the cases in quantity until they fell was noticed some days after the fire. An examination of the exterior of the cases showed that the water worm had kept cool the iron near it; in fact it was possible to trace the extent of the worm by the appearance of the outside of the case. The worms were not in contact with the case, hence the cooling action must be by conduction to be effective, rather than by radiation; in other words, there must have been a conducting medium inside the case for a considerable time, as well as a supply of water for the same time. Oil was the only medium within the case, and it is established that the water did not fail until the building fell, for it was then that the fire hose became useless through the breaking of the pipe. The three cases are intact and apparently tight as ever. The covers were all in place and uninjured except for a slight warping. It is safe to say that there was no explosion of oil within any of the transformers.

It is possible that the cause or origin of the fire will never be discovered. The evidence available at present indicates that it started on the 2000-volt board as a short circuit, and that the flame ran up to the leads to the oil-soaked floor of the gallery. Once there was fire there, the rest is easily understood.

Distribution

INDUCTION MOTORS.

BY R. F. MARKILL.

THE birth of the induction motor dates back for twenty years, when Walter Baily exhibited his polyphrase motor to the Physical Society of London on the 28th of June, 1879. This motor consisted of a series of poles, each of which was magnetized in turn by primary cells, thus imparting rotation to a copper disc suspended above them.

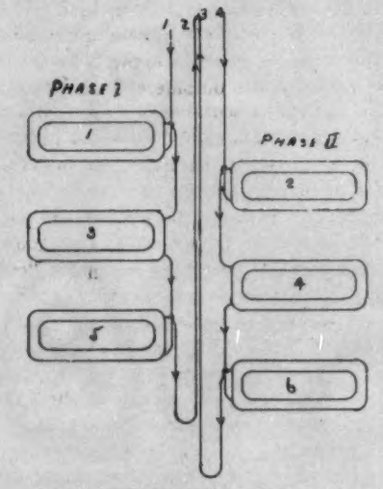
Marcel Deprez exhibited a motor in Paris in 1880 in which he artificially produced two-phase currents by means of a rotating commutator, the current being generated by a battery.

Professor Galileo Ferraris, of Turin, constructed a two-phase motor driven by two alternating currents which were caused to differ in phase by inserting an inductive resistance in one circuit and a non-inductive resistance in the other. A model of this was exhibited at the World's Fair, Chicago, in 1893.

Nicola Tesla worked along these lines between 1887 and 1891. From his early patents the principle of the action of induction motors is thus described: "A motor is employed, in which there are two or more independent circuits, through which alternating currents are passed at proper intervals, for the purpose of effecting a progressive shifting of the magnetism, or the lines of force, in accordance with the well known theory, and the consequent action of the motor.

A number of polyphase motors were exhibited at the Frankfort Exhibition in 1891, nearly all exhibitors being Germans. Messrs. Lehmer & Co. exhibited a model three-phase central station from which were driven a number of small three-phase motors and a 10 horse-power synchronous motor. In the well known transmission from Lauffen to Frankfort, a distance of one hundred and ten miles, a 110 horse-power three-phase motor was employed to pump water for a fountain. A small three-phase motor of 3 horse-power was also driven, having a revolving primary and a stationary secondary—the reverse of the present usual construction.

Professor Silvanus P. Thompson defines a field as "that part of a dynamo in which the magnetism is fixed, while the armature is that part in which the magnetism changes direction." In the induction motor the magnetism is fixed in direction in the rotating part, because as the pole moves the iron moves also, so that their positions remain the same relatively to each other, while in the stationary primary the magnetism reverses with the alternating current. Hence the stationary primary should be called the armature and the revolving secondary the field. This, however, is not followed in practice, the rotating part being called the armature. Thompson coins two



THE INDUCTION MOTOR.

words to overcome the difficulty, calling one the stator and the other the rotor, but we may also speak of them as simply primary and secondary.

All alternating current machines are built up of sheets of laminated iron slightly insulated from each other to prevent flow of eddy currents, which have an injurious effect and cause great heating of the iron. C. E. L. Brown, of Zurich, experimented on different kinds of rotor windings and found the best to be a squirel-cage winding on a laminated iron cylinder. However, various kinds of windings are now used.

The action of the induction motor may be described as follows: When we throw the current on a two-phase induction motor, a magnetism is set up in poles 1 and 3 by phase one, and this is followed by another magnetism that is set up in poles 2 and 4 by phase two, at right angles to the first. This has the effect of a magnetic pole moving along from left to right. The magnetism sets up a current in the secondary winding, and, as it moves along, tends to drag the conductors with it, giving a rotating motion. In a single phase induction motor the magnetic poles do not move along or rotate in this lateral way, and the rotor has to be started by some external force after which it will continue to rotate. The single phase is like a single engine on its center, while the two-phase motor is like a compound engine with cranks at right angles.

When the motor is running, the secondary conductors cut the magnetic lines and tend to set up a current opposite to the

induced current. This is due to an electromotive force similar to the counter electromotive force of a direct current motor, and chokes down the induced current. There is no such counter electromotive force to choke down the current while the motor is at rest and the switch is thrown in to start it, and hence a starting resistance is put in, this having the effect of bringing the current into phase with the electromotive force, as the resistance is large compared with the inductive resistance of the rotor. As the speed increases this is cut out. When the motor is running light and the speed is high the counter electromotive force brings the current down to a very small amount, but as the load is put on and the motor is slowed down the curent is proportionately increased. In order to connect in the starting resistance, collector rings and brushes on the rotor are necessary in some cases, but there are exceptions to this, as for example the Westinghouse Company uses an auto starter* which is in the primary and not any resistance in the rotor. This resistance may be metallic or liquid. Both are used by the Stanley Company, Krupp metal ribbon being used for the one and a solution of carbonate of soda for the other. This resistance is cut out gradually as the motor comes up to speed.

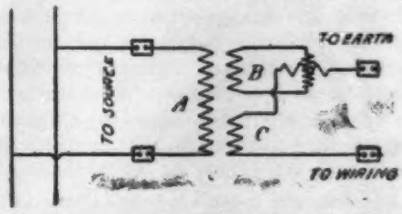
Two-phase motors usually have a separate winding on the rotor for each phase, the two windings being connected at one end and this point connected with the middle collector ring, the other two ends going to the outside collector ring—this being a case where an external resistance is used in the rotor. The field coils are generally wound on forms to fit the poles and connected in series on each half field, the poles on the two half fields being staggard, as the current in the two halves differs by 90 degrees. These two halves are connected directly to the secondary of the transformers or the line as the case may be. Some induction motors have copper "compensating segments," which are simply copper castings forming a closed secondary circuit around the poles. Their effect is to counteract the self-induction of the field coils, the action being similar to the short-circuiting of the secondary of a transformer. There being only one turn in the copper segments, the voltage is very small, but considerable current flows, causing these segments to become quite warm.

One of the great difficulties experienced in the use of induction motors is their effect on the line causing a large wattless current to flow, thus reducing the voltage and severely taxing the generators, and, furthermore, makes lighting very unsteady on the same circuit with motors. This can be somewhat overcome by the use of condensers, the action of which is to counteract self-induction, thus reducing the line current to a minimum and making it much easier to run lights and motors off the same circuit.

Operation

MEASURING INSULATION OF ALTERNATING CIRCUITS.

A DIRECT-READING ohm-meter for measuring the insulation resistance of alternating-current circuits is made by the General Electric Company of Berlin, and is due to Benischke. In Germany it is required that the insulation resistance of circuits be taken with the voltage for which they are intended to be used, and the Benischke ohm-meter was designed for use on moderate alternating voltages. The instrument is an electro-dynamometer and a transformer with circuit connections as shown in the adjoining diagram. The primary winding *A* of a small transformer is connected with the source of alternating current, the voltage of which is that at which the insulation of the wiring is to be measured. There are two secondary windings, the coil *B* being connected with the fixed coil in the electro-dynamometer, while the second one, *C*, is connected through the movable coil to the earth and the other pole to the wiring whose insulation is to be measured. The fixed coil will develop an alternating field of constant intensity; if a current passes through the movable coil the latter will be deflected, the reading being taken on a scale calibrated directly in ohms. The sensitiveness of the instrument may be increased by increasing the number of ampere turns in the stationary coil, which is easily done by means of the transformer shown. The coils *A* and *C* have the same number of windings in order that the voltage at which the insulation is tested is equal to that of the mains; as the readings of the scale are correct only when the voltage is the proper amount, it is necessary



to know whether this is the case. This may be done by the same instrument, which also has a scale of volts and will read the voltage when the two right hand terminals in the figure are connected together. The sensitiveness is so great, that at 120 volts a deflection of one millimeter represents one million ohms; and three millimeters a half million. The instrument has a further advantage in that it is not injured when a new installation is tested in which there may be a dead ground, as in that case it will give the maximum deflection, which means zero resistance. With three-phase installations two readings are necessary in order to find the insulation in one of the three wires, and in installations having a neutral point, the insulation of the whole wiring can be measured by connecting the high tension winding of the transformer between the neutral point and the earth. Further details concerning this interesting instrument will be found in the *Electrotechnischer Zeitschrift*, Berlin, for June 8, 1899.

BREAKING HEAVY HIGH TENSION CIRCUITS.*

BY W. L. R. EMMET.

A GREAT deal of work has recently been done on circuit-opening devices for heavy duty. One of the principal troubles in such work is the difficulty of making experiments. We have a testing outfit at Mechanicville, with which we can get from 300 to 400 amperes at 15,000 volts with an inductive load, and at Niagara Falls I have tested some devices with 700 amperes and 13,000 volts and a highly inductive load, the voltage rising to 18,000 when the circuit was opened. In comparison with past experiences these conditions seem heavy, but they are light when compared to those which must be met in some plants that are now being installed.

There is, of course, a limit to the capacity of every circuit-opening device, and as power units become enlarged it will be necessary to provide means for limiting the total amount of power that can be delivered to individual branches; such reactances can be so proportioned that they do not materially interfere with the normal operating conditions, and, at the same time, they can so limit the total power delivered that it is kept within the safe range of the circuit-opening devices. Up to the present time such reactances have not been much used. Their introduction naturally somewhat affects voltages, and for this reason may be considered undesirable. By judicious arrangement and proportioning the objections can, to a great extent, be overcome, and there is little doubt that such devices will be much used in the future.

I have prepared sketches of a few circuit-opening devices that have resulted from recent investigations and experiments, and will briefly describe their design.

Figure 1 shows a fuse block in which the fuse is in a state of ten-

*Described in general in the JOURNAL, Vol. VI, page 35, August, 1898. For its principles of operation see the JOURNAL, Vol. VI, page 100, November, 1898.

*Abstract of a paper read the National Electric Light Association, New York, May 23-25, 1899.

sion between two hinged terminals; these terminals are pulled apart by springs and receive current through flexible connections. The fuse is punched out of sheet metal, the narrowest portion being at the middle. It is placed between two blocks of porcelain, a small amount of clearance being provided where the fuse passes through, so that its ends can be freely withdrawn by the movable terminals after the narrow part of the fuse has become ruptured. Around the narrow part of the fuse the porcelain blocks are recessed so as to provide an air chamber; this chamber is vented by a hole in the upper block. The whole device is firmly clamped together, so that the only opening to the outer air is through this one vent-hole. The fuse, being under tension, does not quite reach the melting point before the break occurs. It loses its tensile strength at a low red heat and pulls apart. It is quickly withdrawn by the springs from the air chamber in which it has been broken. A very small amount of the metal is volatilized and its gas is blown out of the vent-hole. For the purpose of preventing any deposit of metal fumes on the porcelain surfaces, these surfaces are lined with muslin that has been treated with shellac or varnish and pressed into the desired shape. This lining

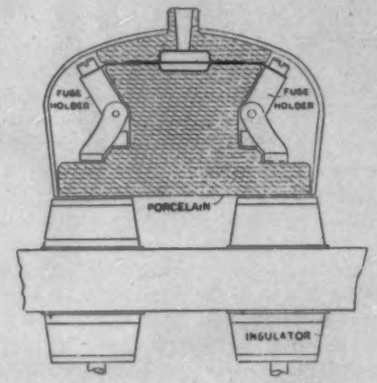


FIGURE 1.—TENSION FUSE.

covers the interior of the chamber in which the fuse is broken and the porcelain surfaces between which the fuse is drawn. These linings are supplied with the new fuses, and are renewed if any appreciable amount of burning has occurred.

With a fuse of this type, occupying a space of six inches by three inches on a switchboard, I have repeatedly broken 300 amperes at 13,000 volts without the slightest injury to the device.

Figure 2 illustrates the principle of a circuit-breaker that has produced excellent results. Two terminals are placed side by side on a vertical board, and are separated, both in front and behind the board, by high barriers. Into the metal surrounding these terminals stout fibre tubes are attached, which extend downward on either side of the barrier. Two copper rods, connected at the bottom by a crosshead, are inserted in these tubes, and forced upward until they make contact in the terminals; the circuit is thus established through the copper rods and the crosshead, around the lower extremity of the barrier, and through the fibre

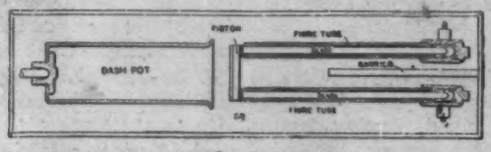


FIGURE 2.—PISTON FUSE.

tubes. The crosshead carries a piston, and this piston moves in a long, air dash-pot. To set the circuit-breaker, the rods are forced upward, by means of a wooden rammer, until the contacts are made; in this position the rods are held by a latch, controlled by a solenoid. When the proper amount of current is put through this solenoid the latch is released; a spring starts the rods downward, so that the circuit is broken in both tubes; the gas produced by the arc expels the rods rapidly from the tubes, the acceleration being checked by the dash-pot. This device has been found very effective on the heavy circuits with which we have experimented. It occupies a small amount of space and is simple in its mechanical construction.

Figure 3 illustrates the construction of a switch or circuit-breaker somewhat similar in principle to that shown in Figure 2. In this case the terminals are at the lower end and are situated inside of vessels into which the fibre tubes project for a short distance.

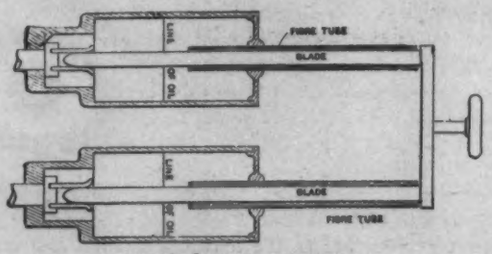


FIGURE 3.—OIL-BREAK FUSE.

These vessels are partly filled with oil, the break occurring below its surface. In the switches of this type which we have designed the rods have been withdrawn from the tubes by a pneumatic cylinder. The presence of the oil materially increases the breaking power of the switch, and reduces the violence of the explosive effect when the circuit is opened.

Figure 4 shows a shunt-fuse device that has been used in connection with circuit-breakers at Niagara Falls and elsewhere. The object of the design is to produce a fuse that can be placed in shunt with the circuit-breaker, to open the circuit after the main contacts are broken. It is, of course, desirable so to design such fuses that they can be very easily replaced. The fuse is placed in a slot in a long, wooden rod; this wooden rod is covered by a paper tube, and part of the rod is cut away at three points so as to form air chambers inside of the paper tube. The rod is inserted in a long, wooden tube, provided with vents that come opposite to these air chambers, when the fuse is in place. The fuse is a small copper wire, and is attached to ferrules on the rod which make contact with springs at both ends of the tube. When the current

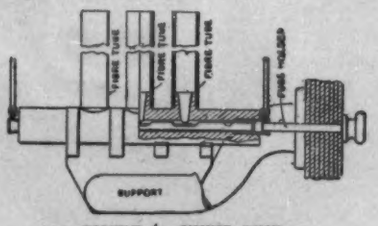


FIGURE 4.—SHUNT FUSE.

is diverted into the fuse, which immediately volatilizes, the pressure in the chambers bursts the paper opposite the vents and the gas escapes through chimneys provided above the vents. The paper covering of the rod prevents the hot gas from getting into the interior of the tube; consequently the device can be used over and over again without any deterioration. These fuses have worked perfectly in parallel with circuit-breakers under the most difficult conditions that we heave yet been able to produce.

HIGH-TENSION SWITCHES AT BAKERSFIELD.

FOR nearly two years the Power Development Company, of Bakersfield, Cal., has been using a novel form of high tension switch and fuse combined with perfect satisfaction during all the kinds of weather peculiar to that portion of the State. The switch is used on all branch lines and at all pumping stations of the Kern County Land Company, the potentials handled by it varying between 10,000 and 11,000 volts. It is essentially an outdoor switch, is of the triple pole, double break type, and is used principally as a means of cutting out the secondary sub-stations for inspection and cleaning.

The features of the switch are so clearly shown in the ac-

companying views that detailed description is unnecessary. In general, it is erected in a frame supported by two poles just outside the station. Within the frame is pinioned a 4x4 timber carrying three arms, which in turn support the switch clips that, as well, form the terminals of a copper wire fuse twenty-eight inches in length. The switch is controlled by

THE WHORFF HIGH-TENSION SWITCH AS ERECTED.

sash cords manipulated from within the station, and the double break as well as the mode by which ordinary line insulators are made to preserve insulation is clearly brought out in the illustrations.

It is only necessary to add that in refusing the switch, the tube is removed from the clips which support it on the arm of the switch; also, that the design of the switch and fuse is due to Frank T. Whorff, Superintendent of the Power Development Company at Bakersfield.

FARMING BY ELECTRIC POWER.

NOW that the pumping of water for irrigation purposes by electric power has become a well established field of usefulness for electrically transmitted power, it may be well for transmission companies supplying power to the great valleys of California to devote some attention to the development of an equally important field, namely, electric farming. In Germany, contracts are taken by electric companies for farming by electric power, including ploughing, harrowing, sowing and harvesting, while recently, according to a Canadian electrical exchange,* the Canadian Pacific Railway Company has tested the use of steam power for agricultural purposes at Morden, Manitoba, in which the engine moved at a speed of one and one-quarter miles per hour, and dragged after it a gang of ten plows, which turned over a width of twelve feet of earth of a depth of four inches. No information is given regarding the horse power of the engine, but it is stated that herbage cut on the prairie a few days previous was burned and that the machine was capable of plowing twenty acres daily, which, at the usual cost of $3.00 per acre, would seem to leave a margin for profit to a transmission company.

*According to C. Pio, in *Elettricita*, of Milan (Vol. 18, pp. 117-120, 1899), the bridging of the pole pieces of rotary converters by copper plates to avoid pumping, occasions a loss of power of about 1.5 per cent.

Canadian Electrical News, October 1899, page 216.

Personal

CLARENCE A. ROSS, manager of the Chicago office of the Sawyer-Man Electric Company, was a recent visitor to the Coast.

SIDNEY SPROUT has retired from the Rawhide mine to resume practice as consulting and constructing electrical engineer, with offices at 106 sixth floor, Crocker Building, San Francisco.

A. M. HUNT and WYNN MEREDITH have been appointed engineers for the mechanical, hydraulic and electrical installation of the proposed Truckee-Virginia transmission to the Comstock mines.

C. E. DUTCHER, chief electrician for the Comstock Pumping Association, has been appointed superintendent of construction for the Truckee River General Electric Company, with headquarters at Virginia City, Nev.

LEO DAFT, well known throughout the electrical world for his pioneering experiments in electric traction on the Ninth avenue elevated road in New York City in 1887, has returned to this country after a long trip through Australasia and the Orient.

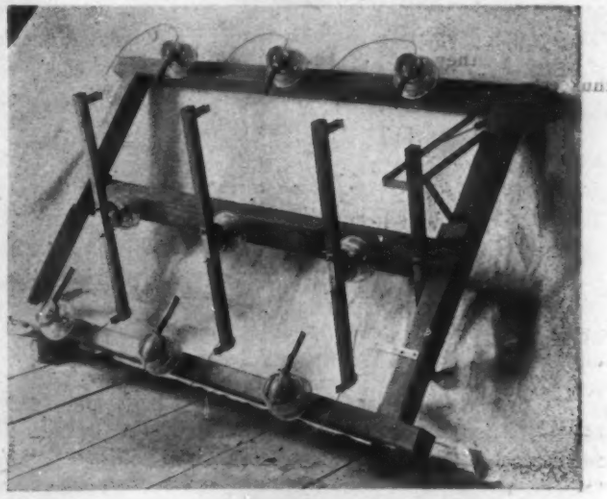
W. A. BURKHOLDER, having finished his contract for the building of the transmission lines for the Mount Whitney Power Company, has gone to Phillipsburg, Montana, to build a transmission plant for the Montana Water, Electric Power and Mining Company.

F. C. CROSBY, of the engineering corps of the Standard Underground Cable Company, Pittsburg, Pa., has arrived in San Francisco to take charge of the installation of the underground cable in the conduits of the Independent Electric Light and Power Company.

PHIL. S. TAYLOR has accepted the position of assistant to R. S. Masson, superintendent of the Independent Electric Light and Power Company, San Francisco, and he has, in consequence, resigned from the operation engineership of the San Gabriel Electric Company, Los Angeles.

E. E. STARK, B. S., formerly engineer for John Martin and the Pacific Coast agency of the Stanley Electric Manufacturing Company, and more recently managing engineer for the Ferrocaril Electrico Jalapa a Cordoba, Jalapa, Mexico, has returned to San Francisco in acceptance of his former position with Mr. Martin, vice T. E. Theberath, resigned, who has become engineer for the Yuba Electric Power Company.

"THE JOURNAL OF ELECTRICITY, POWER AND GAS is a very interesting periodical. The writer takes a good deal of pleasure in running through it thoroughly. There is much in it of engineering value," writes the general manager of one of the largest electrical manufacturing companies in a letter of recent date.



DETAILS OF THE WHORFF HIGH-TENSION SWITCH.

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Devoted to the Conversion, Transmission, and Distribution of Energy.

Conducted by GEO. P. LOW.

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EDITORIAL.

POLYPHASE TRACTION AGAIN.

The editorial appearing in these columns for August on "Polyphase Electric Traction" has brought about considerable discussion, and among the suggestions that have been received pertaining to the subject are two of especial merit. There are indeed many sides to the question presented, but in addition to the schemes detailed in the editorial referred to, Lieutenant W. Stuart Smith, U. S. N., points out that there is still another way of applying polyphase traction that under some circumstances is not to be overlooked. This new method would be practically limited to train service, and it contemplates power generated and transmitted as polyphase alternating current; step-down transformers located as required and feeding into a low-tension working circuit consisting of two overhead wires with rail for the third side, or of one overhead with rails and a third rail; rotary transformers carried on the train and delivering current to locomotive motors or distributed motors on the cars in multiple units as may be desired. The trains will thus become traveling rotary converter stations requiring no extra attendance, and as moderate size static transformers can be frequently located, the weight of overhead structure can be kept within reasonable limits.

Under some circumstances, as stated, this suggested method would be of undoubted value, and it seems that it would be of exceptional utility as affording a means of eliminating such difficulties as may attend the picking up of comparatively high-tension currents as is contemplated in the suggestion proposing the placing of step-down transformers and rotary converters on the locomotive. Opinions differ as to the electromotive force which can be reliably and safely taken to the locomotive through the media of traveling trollies. Some who are skilled in high tension applications place the limit at 2000 volts as a maximum with preference for a lower potential, while others of equal experience and judgment state that they would not hesitate to apply 5000 volts to the trolley in overhead polyphase traction work. Lieutenant Stuart Smith's suggestion however, obviates the difficulties which attend the use of these high pressures.

The means by which the three-phase high-tension current may be taken to the locomotive is in no event the simple process that it may appear to be. Three-phase current will of course be used if for no other reason than that it requires a lesser number of traveling contacts than any other system. Naturally, the rail will form one side of the circuit, as is universally done in direct-current railway practice. The other two sides of the three-phase circuit must then be taken either from two overhead trolley wires or from a single trolley and a third rail as above suggested. In the first instance, the two trolley poles must be separate and entirely independent—which is easy—and the two trolley wires must be highly insulated from each other under all conditions of service and of weather—which is difficult. As to the third-rail system, its use can hardly be considered seriously in high-tension polyphase traction unless it be applied to elevated railway service.

Another correspondent deals solely with methods of control for induction motors when used for railway work, and in his communication is discussed five systems through the use of either of which such motors may be made to fulfill the conditions imposed in various degrees of satisfaction. These five methods are:

First: By the use of motors having primary and secondary wound for the same voltage, alternations and number of poles. With this method, regulation for half-speed and below is effected by connecting the primary of the first motor to the line, the secondary of the first motor to the primary of the second motor, and short-circuiting the secondary of the second motor through suitable resistance. On the other hand, regulation from half-speed to full-speed is obtained by putting the primaries of both motors to line, and short-circuiting their secondaries through suitable resistance. The coupling of motors in this manner is sometimes termed placing them in concatention.

In this case the impressed voltage is kept constant, but the controller with the accompanying resistance is altogether quite complicated. Where the two motors are in series, and the primary of the first is connected to line, the exciting current of the first is double its normal exciting current and it has practically double the losses, which give rise to very undesirable conditions.

Second: The use of two motors wound as in the preceding case, but which are not operated in series. In this case, speed changes of all degrees up to full speed are accomplished by the introduction of resistance into the secondary windings of the motors.

Third: The use of motors containing primary windings of usual forms and squirrel-cage secondaries, the changes of speed therein being effected by means of variable impressed voltage.

Fourth: The use, preferably, of a single motor containing eight poles with leads brought out so as to connect the same windings for four poles, the secondary being of the squirrel-cage type. With this method the controller is complicated on account of the many connections necessary to change the number of poles from four to eight, and to the further fact that the eight-pole combination takes current at approximately one-half the voltage as does the four-pole combination.

Fifth: A motor or independent motors having primaries which are wound with two separate windings, one being for a complete four-pole winding and the other being for a complete and separate eight-pole winding, the secondaries being of the squirrel-cage type. Variations in speed, when this method is used, are obtained by changing from one winding to the other and also by varying the impressed voltage. The controller for this method is not very complicated.

Method No. 1 possesses the disadvantages that the first motor is apt to be much overloaded and the controller is complicated.

Methods 2 and 3 are much used for crane work, but both are inefficient at low speeds. Each have the advantage of simplicity, the latter being the more simple because of its squirrel-cage secondary. The relative advantages between the two depend upon whether the speed curve in No. 3 can be made practically a straight line without sacrificing the efficiency or power factor more than in case 2.

Methods 2 and 3 can be used successfully for heavy traction where long-sustained slow speed is not necessary.

Methods 4 and 5 depend upon the use of a different number of poles for giving two distinct synchronous speeds.

With No. 4, the complications are in the controller.

With No. 5, the complications are within the machines, but the controller becomes simple.

The hope for alternate-current electric traction lies between methods 4 and 5 until something better appears. Experience has shown that in street car work, two speeds are practically all that are required for continuous, long-sustained runs, and it is reasonable to believe that with the two speeds given under methods 4 and 5, the problem may be solved.

THE BLUE LAKES FIRE.

The details attending the destruction of the power house of the Blue Lakes Water Company, near Mokelumne Hill, early on the morning of November 1st, are given on another page of this issue and the interested public will be glad to know that the report of the fire as there given is authentic, as it emanates from the officials of the company upon which falls the burden of the loss. The plant was uninsured and its destruction was almost total, for practically the only salvage will rest in the generators and water wheels which can be put in service again at a comparatively slight cost. It is understood that the plant will not be rebuilt upon the old site but instead a new station will be erected some two miles further up the Mokelumne River where better reservoir sites and a higher head are available.

The catastrophe has excited much interest if not concern, principally because of the fact that it presents the first instance of the destruction of an electric transmission plant by fire, and, secondarily, because of the rapidity with which the structure was consumed. Of the first cause of interest, nothing need be said beyond extending the reminder—so prone to lay dormant and unheeded—that no building containing wooden floors, partitions and platforms, can or ever will be fire-proof. In the present case the framework of the building was of steel, the roof and sidings of corrugated iron, and the foundations and wheel and generator pit were of concrete. The electrical equipment throughout was of types which are accepted as fire-proof the world over, and so far, but no farther, could the plant be accepted as an A1 fire risk; for the presence of wooden floors, partitions and platforms more or less oil-soaked, and of great quantities of oil, all conspired to wreck the plant at the fatal moment when at last the unexpected occurred.

But it cannot be said that the occurrence of fire amid such surroundings should be altogether unexpected unless it be by the companies themselves, each of which that has undergone similar experiences has found too late that it has been under the hallucination that *its* plant could not burn. Insurance adjusters know this story too well, for it is told with variations at each settlement of a fire loss. Anything, everything, will burn, but the liability of fire will be reduced if not practically eliminated, by the rigid exclusion of every piece of timber and of every combustible from within the premises. This is not impossible in central station practice, if wire insulations alone be excepted, but to the contrary it expresses hard common sense, if self-preservation is a desideratum.

The lessons of the fire are few, but they are potent.

First, make power houses fire-proof and provide them with fire-fighting facilities according to the instructions of fire underwriters.

Second, do not concentrate all exciter, generator, transformer and station wiring, instruments and devices into a single switchboard—instead, separate them wherever possible, keep all interlinking wires, feeders and bus bars in roomy subways, and, in brief, segregate all station equipment so that each piece of apparatus shall be independent of all others as to methods of protection and control, to the greatest possible degree.

Third, the vitals of an electrical system are located in its power house, the destruction of which in an hour may occasion losses in business and prestige which might consume a decade in rehabilitating. Finally, of the many thousands of dollars, if not tens of thousands of dollars, that are being spent in the betterment and extensions of water supplies, pole lines and general plant, spare a few hundreds for the improvement of power houses and substations as fire-risks. If not, your plant may be the next to burn for thus far by no means all electric power houses are invulnerable to loss by fire.

Gas

INDUSTRIAL GAS.—VIII.

BY FRANK H. BATES.

VAPOR TENSION OF LIQUIDS. The pressure due to the tendency of volatile liquids to evaporate is termed vapor tension.

Vapor escapes from the surface of volatile liquids more or less readily at all temperatures, creating a pressure which varies with the temperature and is dependent upon the nature of the liquid. With the same liquid however, under like conditions of temperature, this pressure or vapor tension, as it is termed, remains constant.

With increase of temperature the vapor tension becomes greater, until it equals the external or atmospheric pressure, when what is termed boiling occurs—bubbles of vapor forming, and, in bursting, violently agitating the surface of the liquid.

Vapor tension varies with the nature of the liquid; it is consequent then, that the temperatures at which *different* liquids boil will vary under like conditions of pressure.

The boiling point is defined above as the temperature at which the vapor tension becomes equal to the external pressure; it follows then, that as the external or atmospheric pressure varies, the boiling point also changes. With a decrease of the external pressure acting upon a

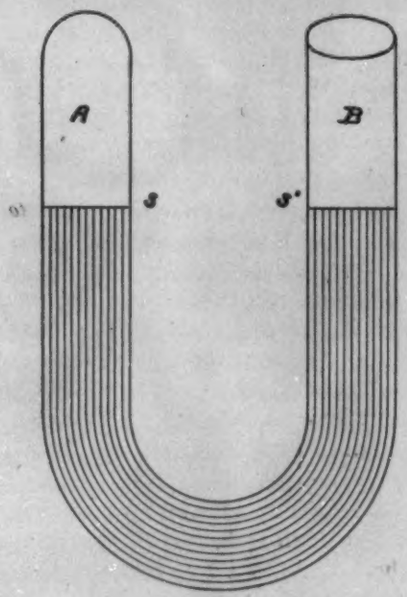

FIGURE 26.

liquid, the temperature of boiling is reduced, since the vapor tension need not become as high to equal the external pressure, and similarly with increased external pressure the boiling point is raised.

At the temperature of boiling the vapor tension equals the external pressure; this fact affords a ready means of determining the tension of different liquids, since it is but necessary to note the external pressure (by means of a barometer if atmospheric), and the temperature at which the liquid boils.

Effect of Vapor Tension on Volume. When a gas is measured over a liquid such as water or mercury, part of the gas volume may be vapor, dependent upon the temperature at which the measurement is made. To assist in separating the true gas volume from the liquid vapor, Table II has been compiled, since by previously determining the vapor tensions of the liquids employed for different temperatures, we may easily make corrections for the measured volumes. The accompanying illustration will serve to make this clear. It is desired to measure the volume of a gas, over water, in the closed arm A of the U tube, Figure 26. The water over which the measurement is made is at the same level as s and s' in both arms of the tube, indicating an external pressure equal to that within the closed arm. The pressure in the latter is, however, made up of both that exerted by the gas volume and that of the vapor tension. If we let

P_a = the atmospheric pressure in millimeters of mercury = the barometer reading,

P_t = the tension of water vapor at the temperature at which the measurement was made (found in Table II of vapor tensions),

P = the net or true pressure exerted by the gas to be measured.

Then,

P (true pressure) = P_a (atmospheric pressure) $- P_t$ (vapor tension).

Consequently, in taking account of the tension of vapor in the measurement of a gas volume, it is but necessary to find the true pressure (atmospheric less pressure due to vapor tension) for use in reducing to standard conditions.

The true or net pressure will, of course, always be less than atmospheric or that indicated by the barometer.

Let us consider the following example:

A volume of ethylene, C_2H_4, measured over water, under a pressure of 750 millimeters of mercury, and at a temperature of 21° C., gave a volume of 2 liters. What would its volume be under standard conditions of pressure and temperature, and when making correction for vapor tension?

We have:

Pressure measured under... = 750 mm. of mercury,
Standard pressure..... = 760 mm. of mercury,
From table, vapor tension of water at 21° C..... = 18.495 mm. of mercury,
Pressure corrected for vapor tension = 750 − 18.495... = 731.505 mm. of mercury,
Temp'ture measured under = 21° C., or 273 + 21... = 294° C., absolute,
Standard temp'ature = 0° C. = 273° C., absolute.

We have then:

$$2 \times \frac{750}{760} \times \frac{273}{294} = X, \text{ or } X = 1.83 \text{ liters}$$

as the volume when the pressure is uncorrected for vapor tension; and

$$2 \times \frac{731.505}{760} \times \frac{273}{294} = X, \text{ or } X = 1.78 \text{ liters}$$

as the volume when the pressure is corrected for vapor tension.

1.83 − 1.78 = 0.05 liters = the difference due to the

presence of water vapor, which, had it not been taken into account, would have been considered as gas.

The foregoing tends to emphasize the necessity of making corrections for vapor tension where great accuracy is required in the measurement of gas volume.

When a gas is measured over a liquid not easily volatile at ordinary temperatures, such as mercury, it may be saturated, previous to measurement, with water vapor by simply introducing a drop or so of water.

When the measurement is made over water, the gas will always be saturated. This is a necessary condition in order that use may be made of the tables of vapor tension, the tensions being known only for saturated gases.

In measuring perfectly dry gases over mercury at ordinary temperatures, no correction for vapor tension need be made, since the tension of vapor of mercury is but slight, and furthermore, is offset by a like tension of the mercury of the barometer at atmospheric pressures. It is but necessary in this case then, to simply make certain that both the barometer and gas volume being measured, are subject to like temperature and pressure, when the mercury of the barometer will stand lower on the scale by just the amount of the tension of mercury, due to the temperature acting on it, giving a reading therefore, equal to the true pressure to which the gas volume is subject.

In event of gases being measured over mercury at temperatures higher than the barometer is subject to, then the difference of vapor tension at the two temperatures (that of the barometer and that of the gas volume) should be subtracted from the atmospheric pressure to determine the true pressure.

The expansion of mercury at high temperatures must also be taken into account. The preferable method is, therefore, to keep the temperatures of both the gas volume (to be measured over mercury) and of the barometer the same whenever possible, thus obviating all necessity for correction for the tension or expansion of the mercury.

Table III gives the tension of mercury vapor at various temperatures.

HEATING VALUE OR CALORIFIC POWER.

By *calorific power* is implied the quantity of heat which may be derived from the combustion of unit volumes or unit weights of a given fuel.

The term *combustion* may be defined as rapid chemical combination, and is generally considered as the combination of some element or elements—usually carbon or hydrogen or both—with oxygen, with a resulting evolution of heat and light.

To facilitate comparative measurements of the heat of combustion of various substances, a *quantitative unit of heat* has been adopted as standard. This, for the English-speaking countries, is the British thermal unit, and for the French-speaking countries, the calorie.

The *British thermal unit* may be defined as the quantity of heat which is required to raise the temperature of one pound of pure water one degree Fahrenheit, at or near 39.1° F.—the temperature of maximum density of water.

The *calorie* is the quantity of heat which is required to raise the temperature of one kilogramme of pure water one degree Centigrade, at or about 4° C., which is equivalent to 39.1° F.

Since both the French and English systems are used in the measurement of quantity in this country, a knowledge of how to convert a unit of one system to the other is often of assistance when tables are not accessible.

To change degrees Centigrade to Fahrenheit or Fahrenheit to Centigrade. In the Centigrade thermometer the freezing point of water is taken as 0°, and as 32° on the Fahrenheit. The boiling point of water is taken as 100° on the former and as 212° on the latter. This gives a range of 100 degrees between the freezing and boiling points of water on the Centigrade scale, and of 180 degrees on the Fahrenheit; consequently, designating degrees Centigrade and Fahrenheit by C. and F. respectively, we have:

$$C. : F. :: 100° : 180°; \text{ or,}$$

$$C. = \frac{100}{180} F. = \frac{5}{9} F. = 0.556 F., \text{ and}$$

$$F. = \frac{180}{100} C. = \frac{9}{5} C. = 1.8 C.,$$

hence we have, calling t_c, temperature Centigrade, and t_f temperature Fahrenheit:

$$t_c = 0.556 (t_f - 32°) \text{ and } t_f = 1.8\ t_c + 32°.$$

We have then the following rules:

To change degrees Centigrade to Fahrenheit, multiply the degrees Centigrade by 1.8 and add 32 to the product; and, *to change degrees Fahrenheit to Centigrade,* subtract 32 from the degrees Fahrenheit and multiply the remainder by 0.556.

To change British thermal units (B. T. U.) to calories (c.) or calories to British thermal units.

1° C. = $\frac{9}{5}$° or 1.8° F.;

1° F. = $\frac{5}{9}$° or 0.556° C.;

1 kilogramme = 2.2046 pounds;

1 pound = 0.4536 kilogrammes;

1 calorie = 1 kilogramme (2.2046 pounds) of water raised through 1° C. (1.8° F.), or

1 calorie = 2.2046 × 1.8 = 3.968 British thermal units, since

1 British thermal unit = 1 pound (0.4536 kilogrammes) of water raised through 1° F. (0.556° C.), and similarly

1 British thermal unit = 0.4536 × 0.556 = 0.252 calories; consequently

To convert calories into British thermal units, multiply by the constant 3.968, and

To convert British thermal units into calories, multiply by the constant 0.252.

British thermal units are generally given per cubic foot or per pound, and calories per cubic meter (or liter = .001 cubic meters) or per kilogramme.

1 cubic meter = 35.314 cubic feet;

1 cubic foot = 0.02832 cubic meters; consequently

To convert calories per cubic meter into British thermal units per cubic foot, multiply the calories by 3.968, giving

British thermal units per cubic meter, and divide the product by 35.314, when the quotient will be the number of British thermal units per cubic foot.

Since $3.968 \div 35.314 = 0.11236$ the operation may be shortened by simply multiplying the calories per cubic meter by the constant 0.11236. Similarly,

To convert calories per kilogramme into British thermal units per pound, multiply the calories by 3.968, giving British thermal units per kilogramme, and divide the product by 2.2046, when the quotient will be the number of British thermal units per pound.

Since $3.968 \div 2.2046 = 1.8$ (approximately), the calories per kilogramme may be multiplied by the constant 1.8, giving the number of British thermal units per pound directly as in the previous case.

To convert British thermal units per cubic foot into calories per cubic meter, multiply the British thermal units by 0.252, giving calories per cubic foot, and divide the product by 0.02832, when the quotient will be the number of calories per cubic meter.

Since $0.252 \div 0.02832 = 8.898$ (approximately), the British thermal units per cubic foot may be multiplied by the constant 8.898, giving the number of calories per cubic meter directly. Similarly,

To convert British thermal units per pound into calories per kilogramme, multiply the British thermal units by 0.252, giving calories per pound, and divide the product by 0.4536, when the quotient will be the number of calories per kilogramme.

Since $0.252 \div 0.4536 = 0.556$ (approximately), the British thermal units per pound may be multiplied by the constant 0.556, giving the equivalent number of calories directly.

Another unit often employed in connection with the quantitative measurement of heat by scientific writers is the *thermal unit*, which may be defined as the quantity of heat required to raise one pound of pure water one degree centigrade at or about 4° C.

To change British thermal units to thermal units, or thermal units to British thermal units.

Since $1° C. = \frac{1}{5}° F.$, or 1.8° F., and

$1° F. = \frac{5}{9}° C.$, or .556° C.

To convert British thermal units into thermal units, multiply the British thermal units by the constant, 0.556.

To convert thermal units into British thermal units, multiply the thermal units by the constant, 1.8.

The term *temperature* should not be confused with quantity of heat, since it is used but to express the intensity of heat at any one time. A match in burning may develop considerable temperature as well as evolve a certain quantity of heat, whereas a quantity of iron combining with oxygen to form iron oxide or rust, will apparently fail to show any increase in temperature, yet before its combustion is complete the quantity of heat evolved may greatly exceed that resulting from the combustion of the match. Temperature is then but a factor in quantity of heat.

The definition of the unit of heat affords a clue to the

TABLE II.

Tension of water vapor in millimeters of mercury for different temperatures. Also the weight in grams of the vapor contained in a cubic meter of air when saturated.

Degrees Centigrade	Tension in Millimeters	Weight in Grams	Degrees Centigrade	Tension in Millimeters	Weight in Grams	Degrees Centigrade	Tension in Millimeters	Weight in Grams
—20.	0.927		12.	10.457	10.6	26.4	25.588	
—10.	2.093		12.2	10.596		26.6	25.891	
—2.	3.955		12.4	10.734		26.8	26.198	
—1.8	4.016		12.6	10.875		27.	26.505	25.6
—1.6	4.078		12.8	10.019		27.2	26.820	
—1.4	4.140		13.	11.162	11.3	27.4	27.136	
—1.2	4.203		13.2	11.309		27.6	27.455	
—1.	4.267		13.4	11.456		27.8	27.778	
—0.8	4.331		13.6	11.605		28.	28.101	27.
—0.6	4.397		13.8	11.757		28.2	28.433	
—0.4	4.463		14.	11.908	12.	28.4	28.765	
—0.2	4.531		14.2	12.064		28.6	29.101	
0.	4.600		14.4	12.220		28.8	29.441	
+0.2	4.667		14.6	12.378		29.	29.782	28.6
+0.4	4.733		14.8	12.538		29.2	30.131	
+0.6	4.801		15.	12.699	12.8	29.4	30.479	
+0.8	4.871		15.2	12.864		29.6	30.833	
+1.	4.940		15.4	13.029		29.8	31.190	
+1.2	5.011		15.6	13.197		30.	31.548	29.2
+1.4	5.082		15.8	13.366		31.	33.405	
+1.6	5.155		16.	13.536	13.6	32.	35.359	
+1.8	5.228		16.2	13.710		33.	37.410	
+2.	5.302		16.4	13.885		34.	39.565	
+2.2	5.378		16.6	14.062		35.	41.827	
+2.4	5.454		16.8	14.241		40.	54.906	
+2.6	5.530		17.	14.421	14.5	45.	71.391	
+2.8	5.608		17.2	14.605		50.	91.982	
+3.	5.687		17.4	14.790		55.	117.478	
+3.2	5.767		17.6	14.977		60.	148.791	
+3.4	5.848		17.8	15.167		65.	186.945	
+3.6	5.930		18.	15.357	15.1	70.	233.093	
3.8	6.014		18.2	15.552		75.	288.517	
4.	6.097		18.4	15.747		80.	354.643	
4.2	6.183		18.6	15.945		85.	433.041	
4.4	6.270		18.8	16.145		90.	525.450	
4.6	6.350		19.	16.346	16.2	95.	633.778	
4.8	6.445		19.2	16.552		99.	733.21	
5.	6.534	6.8	19.4	16.758		99.1	735.85	
5.2	6.625		19.6	16.967		99.2	738.5	
5.4	6.717		19.8	17.179		99.3	741.16	
5.6	6.810		20.	17.391	17.2	99.4	743.83	
5.8	6.904		20.2	17.608		99.5	746.5	
6.	6.998	7.3	20.4	17.826		99.6	749.18	
6.2	7.095		20.6	18.047		99.7	751.87	
6.4	7.193		20.8	18.271		99.8	754.57	
6.6	7.292		21.	18.495	18.2	99.9	757.28	
6.8	7.392		21.2	18.724		100.	760.	
7.	7.492	7.7	21.4	18.954		100.1	762.73	
7.2	7.595		21.6	19.187		100.2	765.46	
7.4	7.699		21.8	19.423		100.3	768.20	
7.6	7.840		22.	19.659	19.3	100.4	771.95	
7.8	7.910		22.2	19.901		100.5	773.71	
8.	8.017	8.1	22.4	20.143		100.6	776.48	
8.2	8.126		22.6	20.389		100.7	779.26	
8.4	8.236		22.8	20.639		100.8	782.04	
8.6	8.347		23.	20.888	20.4	100.9	784.83	
8.8	8.461		23.2	21.144		101.	787.63	
9.	8.574	8.8	23.4	21.400		105.	960.41	
9.2	8.690		23.6	21.659		110.	1075.37	
9.4	8.807		23.8	21.921		120.	1491.28	
9.6	8.925		24.	22.184	21.5	130.	2030.28	
9.8	9.045		24.2	22.453		140.	2717.63	
10.	9.165	9.4	24.4	22.723		150.	3581.23	
10.2	9.288		24.6	22.996		160.	4651.62	
10.4	9.412		24.8	23.273		170.	5961.66	
10.6	9.537		25.	23.550	22.9	180.	7546.39	
10.8	9.665		25.2	23.834		190.	9442.70	
11.	9.792	10.	25.4	24.119		200.	11688.96	
11.2	9.923		25.6	24.406		220.	17390.	
11.4	10.054		25.8	24.697		224.7	25 atmospheres	
11.6	10.187		26.	24.988	24.2			
11.8	10.322		26.2	25.288				

TABLE III.

TENSION OF MERCURY VAPOR.

Degrees Centigrade	Tension in Millimeters	Degrees Centigrade	Tension in Millimeters	Degrees Centigrade	Tension in Millimeters
100	0.75	180	11.00	260	96.73
110	1.07	190	14.84	270	123.01
120	1.53	200	19.90	280	155.17
130	2.18	210	26.35	290	194.46
140	3.06	220	34.70	300	242.15
150	4.27	230	45.35	310	299 69
160	5.90	240	58.82	320	368 73
170	8.09	250	75.75	330	450.91

TABLE VI.

Owing to the necessity for frequent reference to both the French and English unit of measurement the insertion of conversion tables, etc., has been deemed advisable.

FRENCH MEASURE.

One Millimetre ($\frac{1}{1000}$ of a metre)	0.039370 inches
One Centimetre ($\frac{1}{100}$ of a metre)	0.393704 inches
One Decimetre ($\frac{1}{10}$ of a metre)	3.937043 inches
One Metre (unit of length)	39.370432 inches
One Decametre (10 metres)	393.704320 inches
One Hectometre (100 metres)	3937 043196 inches
One Kilometre (1000 metres)	39370.431960 inches
One Myriametre (10,000 metres)	393704.319600 inches
	or, 6 miles, 376 yards, 0 feet and $8\frac{5}{10}$ inches

TABLE VII.

FRENCH WEIGHTS.

One Milligramme ($\frac{1}{1000}$ of a gramme)	0.0154 grains	=	0.0000022	avoirdupois lbs.
One Centigramme ($\frac{1}{100}$ of a gramme)	0.1543 grains	=	0.0000220	avoirdupois lbs.
One Decigramme ($\frac{1}{10}$ of a gramme	1.5432 grains	=	0.0002204	avoirdupois lbs.
One Gramme (unit of weight)	15.4323 grains	=	0.0022046	avoirdupois lbs.
One Decagramme (10 grammes)	154.3234 grains	=	0.0220462	avoirdupois lbs.
One Hectogramme (100 grammes)	1543.2348 grains	=	0.2204621	avoirdupois lbs.
One Kilogramme (1000 grammes)	15432.3487 grains	=	2.2046212	avoirdupois lbs.
One Myriagramme (10,000 grammes)	154323.487 grains	=	22.0462124	avoirdupois lbs.
One Quintal (100,000 grammes)	1543234.87 grains	=	220.462124	avoirdupois lbs.
One Millier (1,000,000 grammes)	15432348.7 grains	=	2204.62124	avoirdupois lbs.
1016.0475443 Kilogrammes	15680000.0 grains	=	2240.	avoirdupois lbs. = one long ton
0.45359265 Kilogrammes	7000.0 grains	=	1.	avoirdupois lb.
0.37324 Kilogrammes	5760.0 grains	=	1.	troy pound

TABLE VIII.

VOLUME—CAPACITY.

One Cubic Metre	35.314 cubic feet 1.308 cubic yards
One Cubic Yard	0.7645 cubic metres
One Cubic Foot	0.02832 cubic metres
One Cubic Decimetre	61.023 cubic inches 0.0353 cubic feet
One Cubic Foot	28.32 cubic decimetres
One Cubic Centimetre	0.061 cubic inches
One Cubic Inch	16.387 cubic centimetres
One Cubic Foot	28.317 litres

One Liter ($\frac{1}{1000}$ cubic metre or one cubic decimeter)	61.023 cubic inches 0.03531 cubic foot 2.1135 pints 1.0567 quarts (American) 0.2642 gallons (American) 2.202 pounds of water at 62° F.
One Gallon (American—231 cubic inches)	3.785 litres
One Gallon (British—277.274 cubic inches)	4 543 litres
One Quart (57.75 cubic inches)	946.30 cubic centimetres
One Pint (28.875 cubic inches)	473.15 cubic centimetres

TABLE IX.

WEIGHT—MASS.

One Milligramme	0.015432 grains
One Grain	64.799 milligrammes
One Gramme	15.43235 grains
One Grain	0.064799 grammes
One Gramme	0.03215 ounces (troy)
One Ounce (troy—480 grains)	31.10348 grammes

One Gramme	035274 ounces (avoirdupois)
One Ounce (avoirdupois—437.50 grains)	28.35 gram's
One Kilogramme	2.2046 pounds (avoirdupois)
One Pound (avoirdupois—7000 grains)	0.45359 kilogrammes
One Pound (troy—5760 grains)	0.37324 kilogrammes

	Milligrammes to Grains	Grains to Milligrammes	Grammes to Grains	Grains to Grammes	Grammes to Ounces (avoirdupois)	Ounces (avoirdupois) to Grammes	Grammes to Ounces (troy)	Ounces (troy) to Grammes	Kilogrammes to Pounds (avoirdupois)	Pounds (avoirdupois) to Kilogram's
1 =	0.01543	64.7989	15.43235	0.064799	0.035274	28.3495	0.03215	31.10348	2.20462	0.45359
2 =	0.03086	129.5978	30.86470	0.129598	0.070548	56.6991	0.06430	62.20696	4.40924	0.90719
3 =	0.04630	194.3968	46.29705	0.194397	0.105822	85.0486	0.09645	93.31044	6.61386	1.36078
4 =	0.06173	259 1957	61.72940	0.259196	0.141096	113.3981	0.12860	124.41392	8.81849	1.81437
5 =	0.07716	323.9946	77.16175	0.323995	0.176370	141.7476	0.16075	155.51740	11.02311	2.26796
6 =	0.09259	388 7935	92.59100	0.388794	0 211644	170.0972	0.19290	186.62089	13.22773	2.72156
7 =	0.10803	453.5924	108.02645	0.453593	0.246918	198.4467	0.22505	217.72437	15.43235	3.17515
8 =	0.12346	518.3914	123.45880	0.518392	0.282192	226.7962	0.25721	248.82785	17.63697	3.62874
9 =	0.13889	583.1903	138.89115	0.583191	0.317466	255.1457	0.28936	279.93133	19.84159	4.08233
10 =	0 15430	647.9890	154.32350	0.647990	0.352740	283.4950	0.32150	311.03480	22.04620	4.53590

principles upon which the construction of instruments for quantitative heat measurement are based. They are generally designed so as to allow of the absorption of the total heat of combustion of the substance being tested by a body of water, indicating the quantity of heat either by measurement of the volume and the rise in temperature of the water, or by measurement of the expansion of the water.

(To be continued.)

Generation

REGULATING SECONDARY VOLTAGES.

IN the operation of rotary converters, in feeding both moderately high and low tension alternate current distributions, in controlling series a. c. street-lighting circuits; in adjusting potentials in different branches of unbalanced polyphase or three-wire circuits; in special work such as the manufacture of carborundum,* and, in fact, wherever it is desired to obtain alternating currents of variable pressure, the induction regulator in one or another of its several forms will be found to fully satisfy whatever exigency may be imposed. It raises or lowers the voltage of a circuit, or, in polyphase work, of any leg of a circuit, without change of connection; it varies the voltage continuously without abrupt stops or breaks; it has no moving contacts; its adjustments of pressure are independent of the current in the circuit; it may be controlled by either manual or automatic means; and, in its best forms, its power factor is high.

The earliest type of potential regulator, and which as well constituted the type first installed by the carborundum company, is illustrated diagramatically in Diagram I. Its primary was wound to suit the voltage of the circuit; its secondary was of sufficient capacity to carry the maximum current of the circuit, and its rated output was found in the product of the secondary ampereage into the maximum required rise or drop in volts. In the diagram is given the potentials as used in this

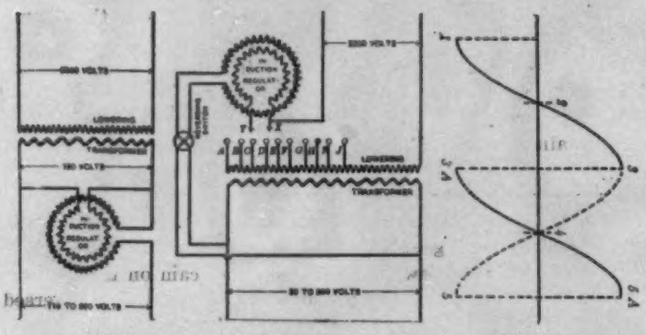

DIAGRAM I. MR REGULATOR. DIAGRAM II. ROWE REGULATOR. DIAGRAM III. VOLTAGE LOOPS.

type of regulator by the carborundum company. The primary of the reducing transformer is connected directly across the 2,200-volt circuit. The secondary is connected in series with the secondary of the regulator, the primary of which is connected to the secondary terminals of the transformer. The regulator is simply a transformer in which the relative positions of primary and secondary windings may be so changed that from a position where the whole flux generated by the primary cuts the secondary effectively and consequently where the secondary voltage is a maximum, the positions may be gradually changed to a point where the primary flux has no effect upon the secondary, and therefore when the secondary voltage is zero. If the movement is continued past the zero point the secondary voltage will begin to increase, but in a reverse direction, until it again reaches a maximum. Since the secondary of the regulator is in series with the secondary of the transformer, its voltage will be added to or substracted from that of the transformer, as the case may be, so that the voltage on the furnace may be varied from the sum of transformer and regulator voltage to the difference between the two. The variation is gradual, and no sudden fluctuations are possible. In the carborundum works the ratio of the transformer is 2,200 to 185, and that of the regulator 185 to 75; there may thus be delivered to the furnace an electromotive force varying from 110 to 260 volts. The output of the transformer is 830 kilowatts. The current will therefore vary from 7,545 amperes at 110 volts to 3,102 amperes at 260 volts. At the lowest voltage the regulator must therefore be able to deliver 7,545 amperes at 75 volts or 565 kilowatts.

An induction regulator of this size is an expensive piece of apparatus to build, for it is difficult to keep cool, and it must be of sufficient capacity to take the entire ampereage of the load. Moreover, its power factor is apt to be low in such enormous units. To obviate this, Norman Rowe, now engineer for the San Francisco office of the Westinghouse Electric and Manufacturing Company, suggested that a combination of the "loop" and "induction" methods of regulation might be effected with very considerable advantage. This method of regulation consists in bringing out loops from the primary of the transformer and of using an induction regulator for stepping from loop to loop on the winding. When it is desired to obtain a variable secondary voltage from a transformer whose primary is supplied with a constant voltage, the simplest method is to bring out loops from the primary or secondary windings, and by means of these loops change the ratio of primary to secondary turns, but this method of regulation is only permissible when small jumps in voltage are not objectionable, and therefore could not be used in this particular plant.

In Diagram II are shown the connections of transformers and regulator where the Rowe method is employed. *A*, *B*, *C*, *D*, *E*, etc., are loops brought out at equal intervals from the primary of the transformer. The primary of the regulator is connected across the secondary terminals of the transformer, while the secondary is in series with the primary of the transformer, as indicated in diagram. Diagram III shows the change in the secondary voltage of the regulator as it is rotated. Suppose the regulator to be in position 1, so that it is generating its maximum electromotive force, and in a direction opposing that of the primary circuit; then the terminal *Y*, being connected to the loop *A*, it is evident that the secondary voltage of the transformer will have its minimum value, for all primary turns are in circuit, and the regulator voltage opposes that of the line. If the regulator be now rotated its secondary voltage will begin to decrease and the secondary voltage of the transformer to increase, until position 2 has been reached, where the regulator voltage, being zero, has no effect on the voltage of the circuit. As the rotation of the regulator is continued its voltage will begin to increase, adding itself to that of the line and increasing the voltage of the transformer. When position 3 has been reached the voltage from *X* to *Y* is exactly equal to the voltage from *A* to *B* (this being the ratio for which the regulator is wound), and *X* and *B* may be connected with no change in voltage on the transformer. In this position the line terminal *X* is connected directly to the terminal *B*, so that *Y* and *A* may be disconnected without spark and without change in voltage. If now the primary of the regulator be reversed, the secondary voltage will be that shown in position 3 *A*, and will be equal to that from *B* to *C*, so that *Y* may be connected to *C*, and then *X* disconnected from *B* without changing the voltages of the system. The regulator now bears the same relation to the point *C* that, at the start, it did to the

*See *The Electrical World*, Vol. XXXIII, page 16, January 7, 1899.

point *A*, so that if the rotation be continued the secondary electromotive force will be gradually increased as before, and at the proper point *X* may be connected to *D*, *Y* disconnected from *C*, the primary of the regulator reversed, *Y* connected to *E*, *X* disconnected from *D*, etc. It will be noted that although in passing from *A* toward *E* the voltage between loops is increasing, the primary voltage of the regulator is also increasing, so that the maximum secondary voltage of the regulator is always just equal to that between adjacent loops. The maximum voltage on secondary of transformer will be obtained when *Y* is connected to *J*, and the maximum voltage of the regulator is added to that of the line. It is evident that to reduce the secondary voltage of the transformer it is only necessary to reverse the direction of rotation of the regulator, so that it moves along the loops from right to left, the minimum voltage being obtained when *Y* is connected to *A*, and the maximum voltage of the regulator opposes that of the line.

The numerous loops from the primary of the transformer and the primary and secondary terminals of the induction regulator are carried to a dial, on which are made the proper changes in connections from point to point. This dial is rigidly fastened to the top of the regulator, a hand-wheel at the side of which is connected through a worm gear to the secondary of the induction regulator, and through bevel gears to the contact fingers on the dial. When the hand-wheel is turned, the secondary of the regulator is rotated until a maximum secondary voltage is obtained; at this point a spring inside the dial, which has been put in tension by the rotation of the secondary, is released and carries through the series of changes necessary in stepping from one contact to the other; *i. e.*, *X* is connected, *Y* is disconnected, the primary is reversed, *Y* is advanced to the proper contact, and *X* is disconnected.

When the transformer at the carborundum works delivers its full load of 750 kilowatts, the current in the secondary of the regulator is approximately 340 amperes, and as the maximum

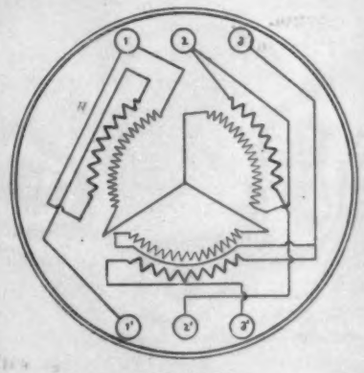

DIAGRAM IV.
THE IRT REGULATOR.

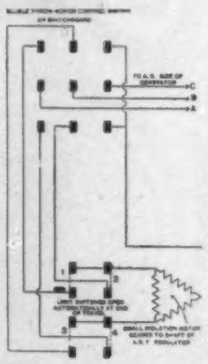

DIAGRAM V.
THE IRT CONTROLLER.

secondary voltage is 100, the maximum capacity of the regulator is only 34 kilowatts. The energy loss in a regulator of this type is much less than that of the earlier forms of potential regulators, and, moreover, as its magnetizing current is very much lower, its power factor is considerably higher.

The General Electric Company has brought out a new form of induction regulator known as the IRT type, which is illustrated diagramatically in Diagram IV. This is the regulator used in the sub-station of the Folsom-Sacramento transmission, at Rossland, B. C., and elsewhere. As in the previous General Electric regulator, it has no moving contacts, but is adjusted by moving an iron core in either direction through an arc of 50 degrees or thereabouts, which varies the inductive effect of a shunt winding on a series coil. How this is done appears in Diagram IV. The IRT regulator resembles an induction motor in form inasmuch as it possesses the usually well defined field or stator, and the rotor as well, the difference between it and the induction motor being that in the regulator the stationary or field windings are in three sections respectively, forming the leg of the main three-phase circuit, or in other words, the stator circuits are in series with the main circuit. The movable, or rotor windings are similarly cut into three sections, which are placed in shunt with the main circuit on the star connection. This movable part containing the so-called rotor windings is mounted on bearings as in an induction motor, and may be moved by hand, although for convenience in operating from a distance there is generally installed a small three-phase motor to drive the core in either direction by a worm gear, the motor being controlled from the switch board in the manner described in Diagram V. The control switch for this function is a triple-pole, double-throw switch by means of which the connections of one of the leads on the small motor is reversed. Electrically interposed between this control switch and the motor, however, are the limiting switches which open the small motor circuit automatically at the ends of travel. The manner in which this motor with its gearing and the limiting switches are mounted on the regulator is shown on page 88 of the JOURNAL for June last. These regulators may, of course, be made for any desired range of voltage.

A 25,000-VOLT DIRECT-CURRENT TRANSMISSION.

DIRECT current generators for the proposed 42-mile 10,000 horse-power St. Maurice-Lausanne transmission in Switzerland, are being built by the Compagnie de l'Industrie Electrique. It is proposed to use direct current at a maximum potential of 25,000 volts, and the generators, which are practically large arc machines, are to deliver constant current at variable voltage.

While no information concerning the details of this proposed transmission is at hand, it probably contemplates the use of the Thury system of power transmission by means of continuous currents, which is in use at the Val de Travers (1,000 horse-power, 10,400 volts, 21 miles), Chaux da Fond and Lock (3,200 horse-power, 14,400 volts, 25 miles), Brescia (500 horse-power, 7,000 volts, 25 miles), and elsewhere. In the Thury system,* the high electromotive force is obtained by coupling a number of series-wound generators in series, the drum winding being used up to 2,400 volts, and above that the gramme. Each generator is carefully insulated, the bed-plate resting on porcelain insulators imbedded in the foundation by means of a cement of sulphur and powdered glass. The coupling between generator and prime-mover consists of a pair of thick rubber discs connected by bolts. Two short-circuiting switches are provided for each generator, one being a hand switch, and the other an automatic switch controlled by a cam on the dynamo shaft so shaped that when the direction of rotation is reversed the switch immediately short-circuits the machine. The power is received at the distant station by means of similar series-wound motors connected in series, and used either directly as such or coupled to constant potential dynamos. Each motor is provided with a special regulator, which maintains the speed constant within 2 per cent. by acting on a shunt of variable resistance connected across the field.

MEASUREMENT OF LIGHT.

According to Abney, the photometric value of the illumination produced by the full moon is 0.012 candle feet, while the actual chemical value of it as shown by the effect on a sensitive photographic plate, is 0.266 candle feet. Very nearly the same ratio holds in reference to sunlight, which is chemically twenty-six times as active as an equal amount of candle light photometrically measured.

*See *Science Abstracts*, 1898, No. 874.

Industrial

In responding to advertisements in this publication kindly mention "The Journal of Electricity, Power and Gas."

INSULATING AND BAKING METHODS.

SOME information of value concerning standard methods of applying insulating varnish in electrical work, together with data for the building of baking ovens and directions for the use of the same, is contained in a circular recently issued by the Stilling Varnish Company. From this circular the following is quoted:

In insulating form-wound armature and field coils, the varnish is kept in a vat into which the coils are dipped without previous baking. The coils are kept in this vat until bubbles cease forming, when they are taken out and suspended directly over the vat, so that the excess of varnish may drip off. They are then carried to the baking room and baked at a temperature of about 85 degrees Centigrade for 12 to 24 hours, according to the size of the coils. By this method the vapor from the moisture contained in the cotton covering of the wire is driven through the coat of varnish during the process of drying.

With large armatures, and in cases where the wire is wound on the core, it is advised that the wire be wound dry, and that dry tape and canvas or linen be used in the ordinary way. The armature should then be placed in the baking room for 10 to 20 hours at from 85 degrees to 93 degrees Centrigrade, and then while still hot painted freely with the Sterling Extra Insulating Varnish and again baked for from 12 to 24 hours. For high resistance work a second coat should be applied in the same way. The fields are treated in a similar manner to the armature, except where inside insulation is desired, in which event they are painted with the varnish as they are being wound and then taped with dry tape, dipped or painted with the varnish and baked, one baking of 20 to 24 hours being sufficient.

Small armatures when wound dry should be given a preliminary baking in order to drive out moisture which is absorbed in the cotton covering of the wire during the process of winding. The armature should then be taken from the baking oven and immediately submerged in the dipping tank up to the level of the commutator, where the armature should remain until the varnsh has had sufficient time to penetrate to the bottom layers of the coils. An indication of this condition is apparent when the bubbles cease to rise to the surface. The armature is then lifted up over the vat, allowed to drip and placed in a baking oven, where it should be baked from 12 to 24 hours.

The baking temperature should not be higher than 93 degrees Centigrade for cotton covered wire, as cotton and paper fibre are destroyed by a higher temperature. The varnish will stand a higher temperature, and for use on metal such as armature core plates, baking at 120 degrees Centigrade is advised.

Further information, prices, etc., may be obtained from the Brooks-Follis Electric Corporation, Pacific Coast Agents, 523-525 Mission street, San Francisco.

TRADE LITERATURE.*

"Lundell Fan Motors, Catalogue 66." An artistic description, with all technical details, of the method of manufacture and features of advantage of Lundell direct and alternating current fans. 40 pages, 7x9 inches. Sprague Electric Company, New York; *Brooks-Follis Electric Corporation*, agents, San Francisco.

"Engine Type Generators." Bulletin No. 4434, illustrating and describing the leading distinctive features of the Bullock direct-current generators, with dimensional data in sizes from 15 kilowatts to 800 kilowatts. Ten pages. Bullock Electric Manufacturing Co., Cincinnati; *Wybro-Hendy Co.*, agents, San Francisco.

"Twenty-two Years' Use of Electrical Apparatus." A brochure illustrating and briefly descriptive of the 1877 and 1899 arc generators of the Brush type. The '99 type of machine itself, together with a number of representative installations of it in the largest sizes, together with station arc switchboards, are tastefully presented. Size, 5x7 inches; No. 1021, 30 pages. *General Electric Company.*

"Bullock Electric Power System for Operating Newspaper Presses." Bulletin No. 4428, illustrating and describing the "teaser" method of motor control for duty imposing variable speeds, as in newspaper presswork. By means of this method of control, economies are introduced which are impossible by other methods. Bullock Electric Manufacturing Company, Cincinnati; *Wybro-Hendy Company*, agents, San Francisco.

"The Victor Telephone Journal." A 24-page periodical of the size of the JOURNAL, devoted to the furtherance of the interests of the Victor Telephone Manufucturing Company and of the independent telephone industry. Although avowedly an advertising medium for Victor telephones, its first issue gives indication that it will contain much information of value to telephonists. Circulation gratuitous. Published at 205-7 South Canal street, Chicago.

"Electro-pneumatic Control for Railway and Other Motors." A 38-page catalogue devoted to a new system of control for electric motors on elevated or other railway service, the system involving the use of compressed air for moving the controlling apparatus, the admission of air into the several parts being effected electrically by means of magnets attached to the air valves. The system is used on an experimental train between East Pittsburg and Wilmerding, the details of which are clearly described. *The Westinghouse Air Brake Company*, Pittsburg, Pa.

"Westinghouse Gas Engines." This is the catalogue for which the mechanical world has been waiting so long. It gives the principles of construction and operation of the Westinghouse gas engine in a way which, in conjunction with graphic illustrations of its working parts, is both simple and convincing, so that, in truth, it really forms a lecture on the working principles of the best type of gas engine thus far produced. The catalogue is gotten out in the usual superb style which characterizes Westinghouse publications. Size 9x7 inches, 67 pages. *Westinghouse Machine Co.*

Westinghouse Bulletins. Standard bulletins, descriptive of Westinghouse apparatus, were publiihed during June, July and August as follows: No. 147-D, "Multipolar D-C. Generators and Motors;" No. 189-B, "Plunger Type Switches for 1100 and 2200 volt A-C. Circuits;" No. 231, "Adjustable Jaw Switches for 600 volts or less;" No. 232, "A-C. Switchboards for Polyphase Circuits of 1100 or 2200 volts;" No. 233, "A-C. Switchboards, Type 8;" No. 234, "Standard Railway Switchboards;" No. 235, "A-C. Switchboards for Polyphase Circuits of 100 or 600 volts;" No. 236, "Single-Phase Alternators, 16,000 r. p. m., 1100 and 2200 volts;" No. 237, "D-C. Lighting and Power Switchboards, Type 5, 750 volts or less." *Westinghouse Electric and Manufacturing Co.*

Wagner Bulletins. These are the standard bulletins issued during October, 1899. No. 27, on "Automobile Charging Outfits" pertains to a self-contained, direct-coupled combination consisting of a Wagner alternating-current induction motor driving a Wagner direct-current generator for charging storage batteries from alternating-current circuits. Efficiency curves and dimensional data are given. Bulletin No. 28, on "Wrought Copper Terminals" is descriptive of a line of new lead and switch terminals which the Wagner company has just brought out. These are of wrought copper instead of the cast alloy heretofore used, and which alloy has a current-carrying capacity of from 30 to 50 per cent. of that of wrought copper. Bulletin No. 29, on "Type C Switches," illustrates a new form of cheap yet reliable and durable knife switch for 50 amperes and potentials not exceeding 250 and 600 volts respectively. *Wagner Electric Manufacturing Company.*

*Catalogues mentioned in this department will be mailed gratuitously on application to the concerns publishing them. When writing, mention THE JOURNAL OF ELECTRICITY, POWER AND GAS. Where addresses are not given, they may be found through reference to the Advertisers' Index on page iii.